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ABSTRACT

Based on the Kellian view of constructive alternativism (that the meanings of any idea are not fixed, but vary from individual to individual), this paper describes a technique for exploring school children's conceptions of common physical phenomena to allow science educators (1) to appreciate the alternative conceptions of their students and (2) to provide learning experiences whereby these conceptions might be modified. The Interview-about-Instances (IAI) method is a technique for eliciting these meanings. The IAI technique consists of tape-recorded dyadic discussions with a student, using a deck of cards (concerned with the applications of one word), as a focus. The method elicits a range of responses revealing the breadth and manner of use of the chosen word. Designing a deck of IAI cards, the process of elicitation, and the transcription of interviews are discussed. Outcomes of the technique, illustrated for the concept "force," are presented. (PN)

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EXPLORING PUPILS' ALTERNATIVE FRAMEWORKS USING THE INTERVIEW-ABOUT-INSTANCES METHOD

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SUMMARY

It is argued that the meanings for words which students bring with them to classrooms are very influential in determining what is learnt there. A detailed exposition is made of a method for eliciting these meanings, called tne Interview-about-Instances technique, and of the method's roots in the Kellian philosophy of 'constructive alternativism'.

Some outcomes of using the technique, illustrated for the word 'Force', are presented. Projections are made of the future applications of the technique.

INTRODUCTION

This paper describes part of a continuing series of efforts to explore and explain school children's conceptions of physics. The work is based upon two fairly rounded principles that, firstly, effective teaching can only take place when it is based upon what the learner already knows. Secondly, if you want to find out what someone knows, then why not ask them.

The realisation that students bring meanings for words, which are commonly used in science, to the science classroom is of longstanding. One view of their consequences for teaching has also been established e.g. Ausubel (1968) refers to 'preconceptions (that are) amazingly tenacious and resistant to extinction'. This implies that such views are, in some essential way, not only 'wrong' but 'bad'. However, another interpretation is emerging. Driver and Easley (1978), referring to them as 'alternative interpretations', observe that "In learning about the physical work, alternative interpretations seem to be the product of pupils' imaginative efforts to explain events and abstract communalities they see between them". Whatever response teachers decide to make to them, such meanings are a genuine part of children's culture.

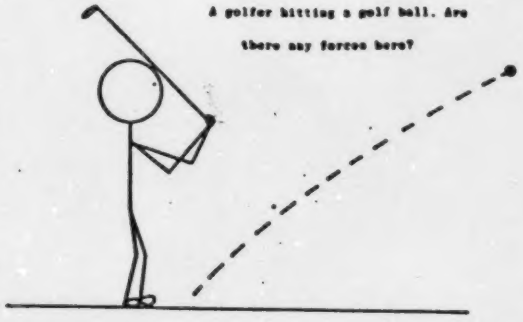
In brief, the position on which this paper is baded derives from a Kellian (1969) view that the meanings of any idea are not fixed, but vary from individual to individual. Concept meanings exist within people, and a concept and can be seen as the stable organisation of a person's experience - to which can be given a label. A concept has a 'range of convenience', the extension of word meanings are always, and necessarily, vague and impermanent. Stable does not mean static. Rather, concepts are continously being integrated, differentiated, expanded to cover new events, and more precisely used with new experiences. Kelly (1980) summarises his notion of constructive alternativism by saying "the assumption is that whatever nature may be, or howsoever the quest for truth will turn out in the end, the events we face today are subject to as great a variety of constructions as our wits will enable us to contrive".

It might be reasonably argued that the more teachers know about and appreciate the alternative conceptions of their students, the more they will be able to provide learning experiences whereby these conceptions might be modified. By 'modified' is meant the enrichment or enhancement of a person's concept to encompass a recognition of a scientist's concept: a movement from 'Children's Science' to 'Scientist's Science' (Gilbert & Osborne (1980)). If 'children's science' is a major feature in the curricular landscape, then attempts to elucidate its characteristics seem called for. Investigators seeing their task as the measurement of the extent to which students have learnt the correct, or 'scientist's science' version of a word meaning, will use 'comparative' methods e.g. multiple-choice questions, open response questions. At the opposite end of the scale, investigators, taking an ethnographic, or non-comparative, approach will wish to examine the use of words in 'realworld' settings. The most usual and complex of such settings is the normal school classroom: both Tasker (1980) and Zylbersztajn (1981) are conducting such studies. The 'simplified classroom' i.e. one where two or three students are given lesson tasks to perform in a separate room has also been used e.g. by Tiberghien (1980). The 'middle ground' between these extremes ie methodologies capable of adaptation to a 'comparative' or 'non-comparative' mode, seems potentially fruitful. Certainly, open response questions can be used in this way e.g. Viennot (1979) as can a modified multiple-choice approach e.g. Helm (1980). It is into this middle ground that the Interview-about-Instances (I.A.I.) technique (Osborne & Gilbert (1980)) Gilbert, Watts and Osborne (1981) has been introduced.

The I.A.I. Technique

In outline, the I.A.I. technique consists of tape-recorded dyadic discussions with a student, using a deck of cards, concerned with the applications of one word, as a focus. A card consists of a line-drawing of a situation which may, or may not, represent an example of the application of the word.

Whatever the student's response, reasons are sought. The method elicits a range of responses, as an example will show. Take, as an illustration, the card about 'a golfer' from a deck on 'force'.



Typical answers are:

S the force is coming from the man who whacks it

(01:17)

S the force is coming originally from his arm and he's giving it to the ball

(04:15)

S yes there is force in the ball.....in the movement.... the whack of the thing

(10:11)

S the force would be in that direction (along line of motion and eventually it would stop going upwards....and start being pulled downwards and so you get a curve....

(06:17)

Included within these quotes are (in brackets) immediate interview questions and, often, some indication of what is being referred to in the discussion. The numbers at the end of each quote refer to the number of the interview and the age of the interviewee. So, (14:13) would be the fourteenth interview which took place with a thirteen year-old. These extracts are taken directly from the transcripts and are unpunctuated and often ungrammatical. A series of dots indicate a pause between phrases, the letter I, means 'Interviewer'.

A deck of such cards, perhaps 15 in number, will reveal the breadth and manner of use of the chosen word over a range of situations.

Designing a deck of I.A.I. cards

The initial design of a deck of I.A.I. cards may be undertaken by following the algorithm presented below (Watts, D.M. (1980a, b, c))

1 To identify and analyse the 'scientist's science' view and meaning for a word. A text book review might isolate a number of views for force:

"force as 'pushes' and 'pulls'", "resultant force equals mass x acceleration", "forces are interactions of nature".

Moreover, it is important that the route by which scientists arrive at a consensus be realised. What scientist's regard as public knowledge exists where there is substantial overlap between the concepts formed by different individuals. And yet even with such a publicly agreed concept like 'force' it is possible to find alternative approaches. O'Sullivan (1979), for instance, has shown that there are four distinct conceptual approaches in current text books to the treatment of Newton's laws of motion.

2 Identify the 'critical attributes' of the word in scientist's science. These are the essential qualities, all of which must be recognised if the word is to be used in a way acceptable to scientists. For 'force', for example, these involve specifying:

(a) its magnitude and direction
(b) the body on which it acts
(c) the body that exerts the force
(d) the nature of the force ie the type of interaction occurring
(e) the effects of the force e.g. changes of direction, size, shape

3 Identify the 'non-criterial attributes' of the word in scientist's science.

These are statements about situations, or circumstances, which are sometimes made and which involve the word in some way. For example, for 'force'.

(a) the weight of an object can be said to act through its centre of gravity

(b) tension is the condition of a body subjected to equal but opposite forces which may lead to an increase in linear dimensions

(c) forces can be measured in 'newtons'

(d) 'surface tensions' can be accounted for in terms of inter-molecular forces

The number of such statements are usually great (around 30 for 'force', at school level), the range being decided by consultation with curricular materials.

The process of choosing attributes is one of 'unpacking' the physics concept, and delineating its common role in school Physics.

4 Identify sources of invalid use of the 'scientist's science' meaning.

The first, and probably major, source is that pool which can be called 'common usage' meanings. These are inevitably numerous: for 'force' examples are 'force of habit', 'force of law', 'forced labour', 'forced march'.

A second group is that which may be termed 'misuse' of the scientist's science meaning. Warren (1979) has identified a collection of misuses for 'force' i.e.

(i) the inclusion of force where none exist, to account for effects noted in a situation.

(ii) the omission of vector components

(iii) an inadequate description of the bodies exerting the forces on the situations in which the interactions are taking place.

5 Review other work in 'children's conceptions'.

Some recent excellent work in the field has thrown up a number of important ideas that can be incorporated in the card design.

A number of recent reports have highlighted the substantive aspects of children's thinking concerning concepts in science. This welcome change of emphasis, away from pupils' logical reasoning, towards the substance of their conceptual frameworks, has prompted new lines of enquiry. Clement (1977), Viennot (1979), Osborne and Gilbert (1980), Watts and Zylbersztajn (1981) have all discussed some concepts of force; Saltiel and Malgrange (1980), Trowbridge and McDermott (1980) and velocity; Nussbaum and Novak (1976), Gunstone and White (1980) about gravity; Erikson (1979) about heat and temperature; and so on.

6 Identify sources of obvious linguistic confusion.

These may be grouped into one of three types: antonyms, synonyms, homonyms. The antonyms for 'force' are 'weakness', 'incapacity', 'enfeeblement', 'tameness'. The synonyms for 'force' are 'strength', 'power', 'impetus', 'violence', 'intense', 'effort', 'military might', 'body of people', 'drive', 'population', 'validity'.

7 Producing cards.

Parts 1 - 6 in this sequence, which have already been discussed above, might be designated as an exploration of potential sources of alternative conceptions. The actual production of cards is a mixture of art and science. What is required is a mixture of 'examples' and 'non-examples'.

Each example would represent all the Criterial Attributes and some of the Non-criterial Attributes: for a deck of cards the intention would be to include most or all of the Non-criterial Atrributes.

Each non-example would have one or more of the Criterial Attributes absent, yet include some of the non-criterial Attributes: over a deck of cards the whole spectrum of combinations of Criterial Attributes would be omitted, and all the non-criterial Attributes included.

That said, the design of individual cards will depend on the insight of the researcher. The over-riding concern must be to have cards which simultaneously allow a wide range of meanings to be demonstrated. Thus they must be interesting to the interviewees: ideas can be sought from the illustrations in text books, from TV and by the simple expedient of asking students and teachers for 'challenging situations'.

The Process of elicitation

The sequence of events in which the elicitation takes place may be summarised as below:

(a) design a deck of cards (see above)

(b) conduct a series of pilot interviews e.g. with about 5 - 10 students covering the age range to be investigated, to remove anomalies in design, wording and sequencing.

(c) conduct 15 - 20 interviews, making fully detailed transcriptions. An inspection of these will show whether individual cards, and the sequence adopted, best facilitates the presentation of student's own interpretation. This will lead to a final review of the deck.

(d) conduct the investigation proper.

The choice of a sample of students, with whom to conduct interviews, is an initial challenge. The I.A.I. approach may be seen to be within the framework of 'case studies'. The problem is: what is the case? If the case is an individual student, who will perhaps be interviewed about a number of words, then any articulate individual is satisfactory.

If the case is the whole of a naturally occuring group e.g. a class, then no problem is encountered for all are interviewed. However, if a selection is to be made from a class, then its basis needs careful consideration. As Pines (1980) has pointed out, interview techniques work best with articulate students and these may not be cognitively representative. If the teacher is asked to select a number of 'about average' students to be interviewed, then the 'articulation factor' is compounded by the natural desire to 'please' the researcher by providing a 'satisfactory' student: this often means a 'good one'. The use of auxiliary tests to select students e.g. Piagetian tests, verbal reasoning tests, seems equally problematic because the relation between scores on these, and 'Children's science', is unclear.

Interviews are best conducted on complete privacy, for only then will the participants relax (provided that neither feels threatened). The amount of extraneous noise on a tape-recording will also be reduced to a minimum. The participants sit side-by-side whilst the interviewer sets the scene for the interview. We have found it useful to say something like 'You will know from your own experience how teachers sometimes use words in classes which do not agree with your understanding of those words. I want to find out how you use a particular word...there are no right answers or wrong answers... so that we can get teachers to see your point of view' is found universally acceptable. The interviewer then asks permission to record the discussion 'because I can't concentrate on what you are saying and take notes': again this is almost always acceptable.

For the interview does take the form of a discussion. From the initial fairly-openended question e.g. "is there a force here?", the purpose of the interviewer is to identify, as accurately as possible, the student's perceptions.

Thus all interviewer response is non-evaluative, supplemental questions being asked until the interviewer has fully grasped the student's ideas. Many of the skills needed e.g. the reflective quotation, are standard in the area of counselling. Thus the deck of cards is proceeded through, reference back to earlier cards being made either at the student's behest, to change an earlier response, or by the interviewer, if there is a glaring discrepancy in the answers given to two cards. At the end of the sequence, or whenever the interviewer has decided that further progress is unlikely, the student is offered an opportunity to revisit any of the cards. By this time the student is usually still relaxed but a little tired: the interviewer's final questions (although they can be placed at the beginning) concern the students prior academic achievements, age, class, previous experience of science teaching and interest in physics. At no point is the student given any evaluation of 'success or failure' .

The transcription of interviews

The transcriber faces a number of challenges in this vital task:

(i) Talk is discontinuous, being punctuated by gestures, faltering, pausing, showing various qualities of voice, and is delivered with a variety of facial expressions and in many body postures.

(ii) The sequence of a conversation is difficult to follow, being full of inconsequence, confusion, pauses and contradictions.

(iii) The tape recorder, whilst ignored for the majority of an interview, can occasionally become the focus of the student's attention.

In short, it is inevitable that a transcript is a translation prepared by the transcriber. Whilst the interviewer will have made notes on some of these features, which should be immediately related to a transcription prepared very shortly after an interview, the transcriber will need to use some precise conventions. Of these, the two most important concern the style and notation of the transcript. In style, it has been found convenient not to punctuate the transcript, nor to divide the speech into sentences and to omit fullstops, commas and the like. The question mark is also omitted, for the verbal inflective associated with questioning is sometimes used to make statements, the truth of which is uncertain to the speaker. Pauses are typed and marked, noises e.g. laughter, included. The transcription is prepared with wide margins (for subsequent annotation) and marked with 'revolution-counter' numbers from the tape recorder. The transcription is best done in two distinct phases. First of all, the words and noises are presented verbatim. Then the tape is replayed, entering intonations, pauses and comments. Irrespective of who does the first part, it must be checked by the interviewer and the latter must undertake the second part.

Some results for the concept of force

In this paper it is not possible to give a full appreciation of all the students' views. The work on 'force' (Watts, 1981) has given rise to the identification of eight distinct conceptions. These are called 'alternative frameworks' from the work of Driver and Easley (1978).

The frameworks described here come from no one pupil. They have been pieced together from the implicit and explicit conceptions used by the children during the course of the interview. Each framework was used by many pupils (at least two) and used often (at least twice) during the interview. The frameworks form a composite picture based on ideas shared by a number of pupils, an approach termed the 'mosaic' method (Bloor, 1973). To a physicist, the frameworks may appear contradictory or even mutually exclusive. This was not necessarily a perception shared by the pupils who advanced them.

The frameworks have been arranged in alphabetical order:

FRAMEWORK A : Affective forces

C : Configurative forces

D : Designated forces

E : Encounter forces

I : Impetus forces

M : Motive forces

O : Operative forces

S : Substantial forces

Each of these has a number of constituent parts. Here, just one of these has been presented, a framework called Configurative forces. The examples given earlier in response to the golf card came from framework D : Designated forces.

C : Configurative forces

C1 Immobility - forces are seen to be required to trap an object into non-movement.

C2 Position - objects have force by virtue of their position.

C3 Constraint - force is required to overcome some resistance, some constraint to activity.

C: Configurative Forces.

There are three parts to this framework. The first part is a notion of force as a bonding between objects that hold them stable in relation to each other. Without that bonding they would not be expected to stay in position, but to move apart. It is a framework that tries to account for the absence of movement. Immobility seems to need a cause and forces, both singly and in combination are described to account for it.

The second part is an idea of force due to an object's position, usually it's height. For instance a ball rolling down a slope would have more force at the top of the slope than at the bottom. Other positions are important too: the stability of an object; the flexing of a diving springboard from its horizontal position. The third part has a suggestion of constraint about it - a pent-up, ready-to-burst configuration. Within this sense for example, a bomb, stationary on the floor but about to explode, would be considered a very large force. The framework can be precised as:

> Objects restrained in a position have force.

C1: Force is in Immobility

Youngsters describe forces in situations where nothing was happening, when they might other-wise expect something to occur.

> *Z. I think it (a force) is holding him up in space...Yes he needs a force to stay there (astronaut in space) (01:17)*

> *S. and that (a force) is what keeps it down instead of flying off when you know there's nothing else pulling it (02:15)*

> *S. there'll be gravity pulling down the table as well and something pushing it....so it keeps the table firm...otherwise the book couldn't stay there (table and book) (02:15)*

I. what is a force,

S. something being held....yes held together by forces (04:15)

C2: Force is in position.

'Position' is seen as an important force. It is concerned with stability and equilibrium - quite a few objects have 'natural' or 'normal' positions. When something is unstable and likely to fall, then it has force.

T. it slows down because it isn't on a slope anymore after that....because if he wants to keep going he'd have to go back to the top of the slope (sledge) (09:12)

J. well...you've got more force the higher up you are....its obvious isn't it....(05:16)

S. the force is actually....in how the torch is positioned (torches) (04:15)

S. well when he's down here....on the sledge (bottom of hill) it's not stable is it...it's umh....it just wants to get to a new position that's along here (along the horizontal) (sledge) (03:15)

C3: Force is in Constraint.

S. I suppose the force is still there....but it doesn't actually happen...if you see what I mean (golfer and golfball) (03:15)

C. it'll try to get above all the air....and force its way above all the air....or try to...but it won't be able to 'cos he's holding it (balloon) (07:14)

S. well it (book) is being held....it's being held to the table so it's kind of force (book and table) (04:15)

G. there must be a force and gravity to keep it on the table ....it isn't going from side to side so....(I. it's just lying there) .....yes....there must be some sort of verical force keeping it on the table (book on table) (12:15)

All three parts to the framework have a sense similar to the physicist's idea of potential energy, particularly gravitational potential energy. It is interesting to speculate on the educational implications for an eleven year-old having an intuitive feel for elastic potential energy, which she calls force. For example Sally (10:11) says

S. well it's like a spring and when you get onto it....I don't know...it's got a force....to push you out....the spring (diving board) (10:11)

Viennot (1979) notes a similar framework for students in their last year of secondary school and first year of university in both Britain and Belgium. She points to 'local' and 'global' types of structures of spontaneous thought and describes 'local' as

'A 'local' or 'static' type which considers the positions of the objects in the system, or its state and which makes a local analysis of the motion and thus uses force of interaction only'.

She concludes, too, that these students also have difficulty in differentiating between the concepts of force and energy. Gunstone and White (1980) also comment on the role that 'equilibrium' plays in student thinking. Using a pulley-stystem demonstration with first year university students at Monash University, Australia, they say:

'Equilibrium was seen in an odd way by many students. It was, during this demonstration, 'shattered', 'lost', 'upset', 'destroyed', 'sought', 'immediately re-established'. 'obtained', systems 'wanted to go back to it'.

It was apparently seen as some sort of real entity contained in objects rather than as a description of a particular physical state'.

The Future use and development of the I.A.I. approach

As regards research, work is under way to:

(a) study children's egocentric views of the world through their own scientific conceptions.

(b) consider how their views change, and at what point in the child's development this happens.

(c) investigate the retention of intuitive ideas despite formal teaching.

(d) examine the language of students in discussing scientific concepts, and consider how this reflects their understanding.

(e) consider how attitudes and orientation towards science can help in the development of concepts.

(f) consider how learning style might affect the development of concepts.

(g) study the relationship between concepts, the 'alternative framework' developed by the youngster.

On the development side, whilst the technique is being extensively used as a research tool e.g. 'gravity', 'friction', 'light', 'living', 'energy', we intend to explore its diagnostic value in the hands of teachers, and self-monitoring value when in the hands of students.

CONCLUSIONS

This paper has been concerned with describing a technique for exploring pupil's interpretations of common physical phenomena. Their conceptions have been described as alternative frameworks, and the application of the technique, called the Interview-about-Instances, has been shown in relation to the concept 'force'.

One particular framework has been used as an example.

Some impression of the commonality of the framework has been provided by reference to the work of others who have noted similar tendencies in interviewing and testing physics students.

Throughout the study children's alternative frameworks have been given a respected status that reflects their widespread use; their internal coherence and logic, and their tenacity in the face of classroom teaching.

The aims of the study has been to provide science educators with a repertoire of common frameworks, and ways in which they differ from the orthodox physics view. By better understanding the beliefs and commitments of pupils about the concept of force, the teacher has a firmer basis from which to choose particular teaching approaches.

Apart from making possible the types of future studies mentioned above, this kind of work might serve the important task of raising teachers' awareness of the difficulties in communicating with children and the need to probe their understanding.

D M Watts
August, 1981.

DMW/MRR

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